T18/B7/UK2/96

IEA SOLAR HEATING AND COOLING PROGRAMME

TASK 18 ADVANCED GLAZING MATERIALS

B7 ANGLE SELECTIVE TRANSMITTANCE COATINGS

Measurement of the angular dependent spectral transmittance of an oriented columnar coating on a low-e substrate

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1. Introduction

The Solar Energy Materials Research Laboratory of Oxford Brookes University undertakes measurements of the optical properties of materials to traceable reference standards. The measurement range covers the ultraviolet, visible, near infrared and infrared regions of the electromagnetic spectrum. Solar, visible and thermal properties are derived from spectrophotometric data. The laboratory is approved by the Ministry of Defence to perform measurements in compliance with Defence Standard DS0023/1[1] and accreditation from the National Measurements Accreditation Service (NAMAS) is currently pending. The Laboratory has participated in a number of round-robin inter-laboratory comparisons within the International Energy Agency Solar Heating and Cooling Programme and co-ordinated a round-robin study of the angular dependant optical properties of architectural glazing on behalf of the Bureau Commune de Reference for the Commission of the European Communities (DG XII)[2].

This report represents the results of angular measurements made on an angular selective sample provided by Professor G. Smith (University of Technology of Sydney, Australia) as part of an inter-laboratory comparison within the IEA.

2. Experimental Procedures

2.1 Instrumentation

The optical specular transmittance spectra were recorded on a Bruker IFS 66 Fourier transform spectrometer with integrating spheres. The measurements were performed with an in-house variable angle specular transmittance accessory between normal and 60 degrees angle of incidence. A Glan-Thompson polariser was used for s- and p-polarisation from 0.6 - 2.5 μm.

The Bruker IFS 66 is equipped with two light sources, three beam splitters and five detectors. It also has its own custom-made external angular specular measurement device with its own detectors. The device and optical layout is shown in Figure 1. It has been designed to measure both spectral reflectance and transmittance values. As can be seen both the transmittance and the reflectance measurements are absolute. Visible and near infrared specular measurements were made using the tungsten source and quartz beamsplitter with a DTGS detecting from 0.6 - 2.5 μm.

2.2 Transmittance measurements

The beam is sent out of the spectrophotometer using an off-axis parabolic mirror, which also makes the converging beam parallel. The height of the beam is easily changed by a beamstearer, which also allows fine alignment. The polariser is placed just before the sample mount in both the background and sample measurements. Another off- axis parabolic mirror mounted on the detector arm then focuses the beam onto the detector after it has been transmitted through the sample. The alignment is checked with an external laser.

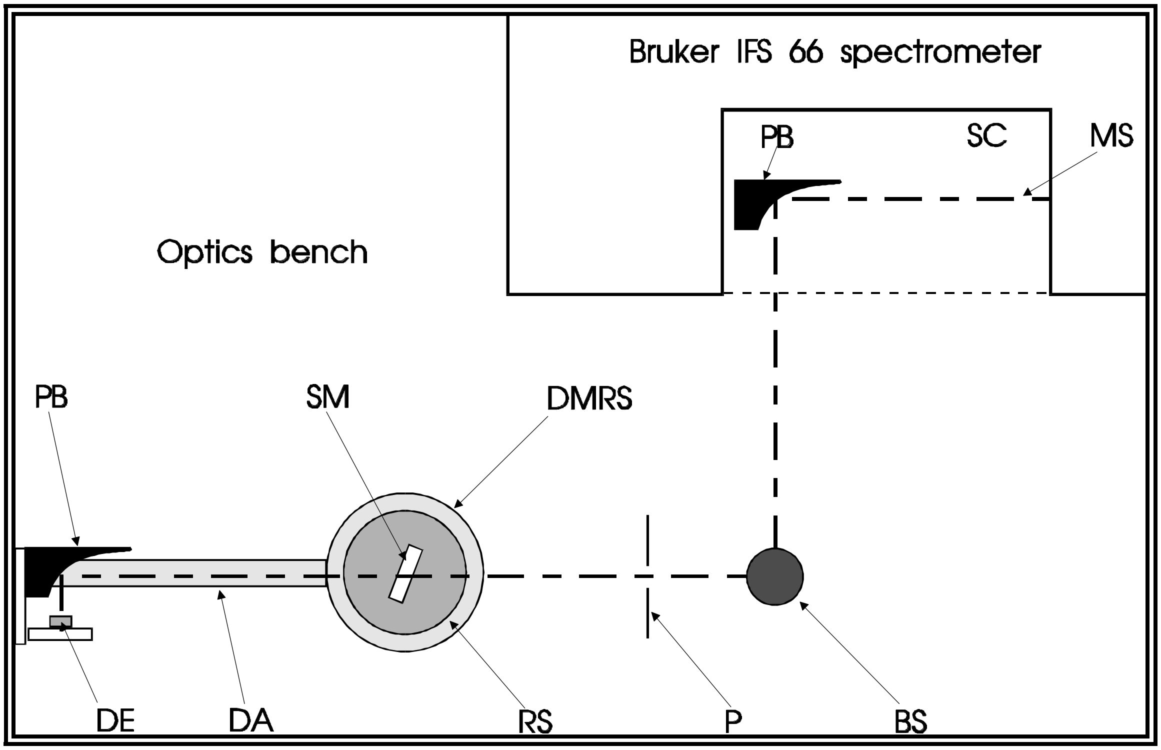

Figure 1 Schematic plan view of the external optics attached to the Bruker IFS 66 spectrophotometer for measuring angular specular transmittance and reflectance.

Legend: BS - beamstearer; DE - detector element; DMRS - detector mounting stage; DS - detector stage; MLS - modulated light source; P - polariser; PB - off-axis parabolic mirror; RS - rotational stage; SC - sample chamber; SM - sample mount.

Once the optics are aligned, transmittance measurements are fairly straightforward. The detector arm is fixed for all the measurements so that it is in a straight line with all the optics after the beamstearer. The background reference is made with nothing in the sample mount so that just air is measured. The sample is then placed in the rotating sample mount at the required angle of incidence, including normal and another measurement made.

The measured transmittance of the sample is then referenced to the background measurement and output by the connected computer.

2.3 Angular selective sample

The sample provided to measure is 2.4 cm^2 and consists of an Al/Al_2O_3 silver film deposited on a low-e ITO layer on a glass microscope slide. The top layer was deposited at an angle, the direction of which was marked on the sample.

The transmittance of this sample was measured as described above. Three angles of incidence, 30°, 45° and 60°, were measured in the solar range either side of the normal, as well as the normal incidence. Both s- and p-polarisation were measured using a Glan-Thompson polariser.

The main problem that had to be overcome was the small size of the sample. This posed difficulties, especially at the higher angles as the beam was larger than the sample An iris, therefore, had to be placed in the beam before the sample mount. The sample mount was also not made for such small samples and had to be temporarily adapted. It was therefore very difficult to make sure that the sample was totally vertical, and so not oriented at an angle to the incidence beam in two different planes.

3.0 Results

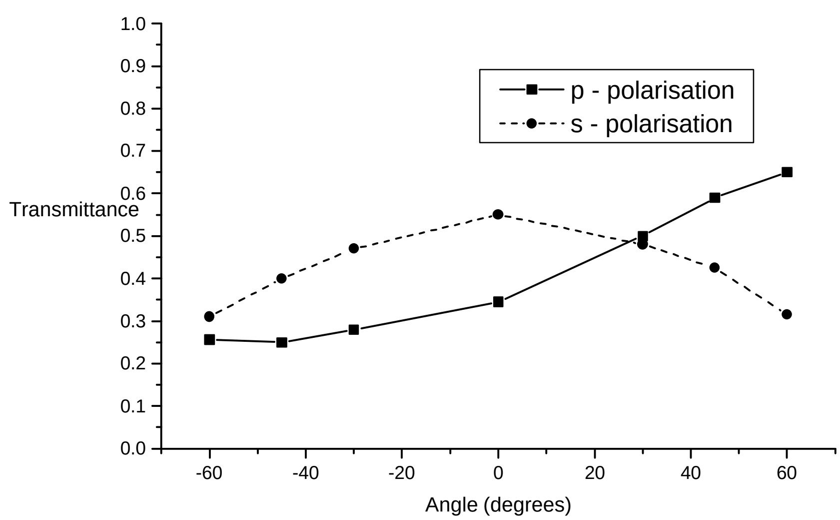

Figure 2 Transmittance of sample at λ = 0.75 μm as a function of incidence angle either side of the normal (-60°, -45°, -30°, 0°, +30°, +45°, +60°).

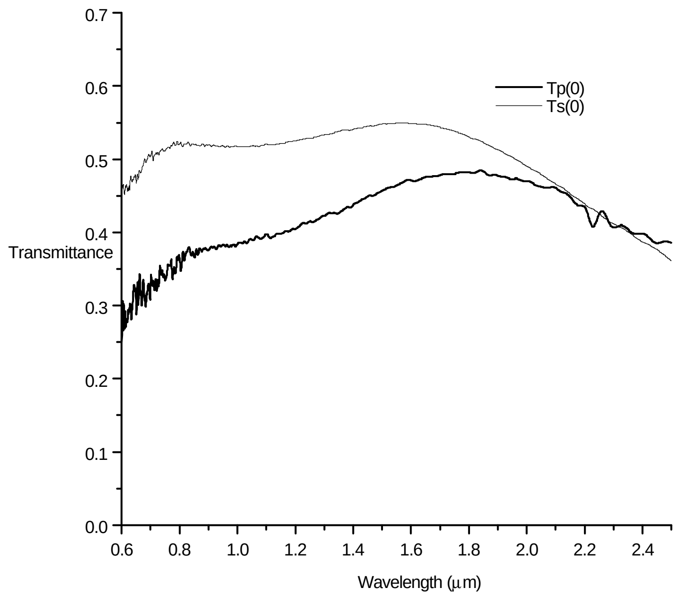

Figure 3 Tp and Ts as a function of wavelength at 0 °, normal incidence.

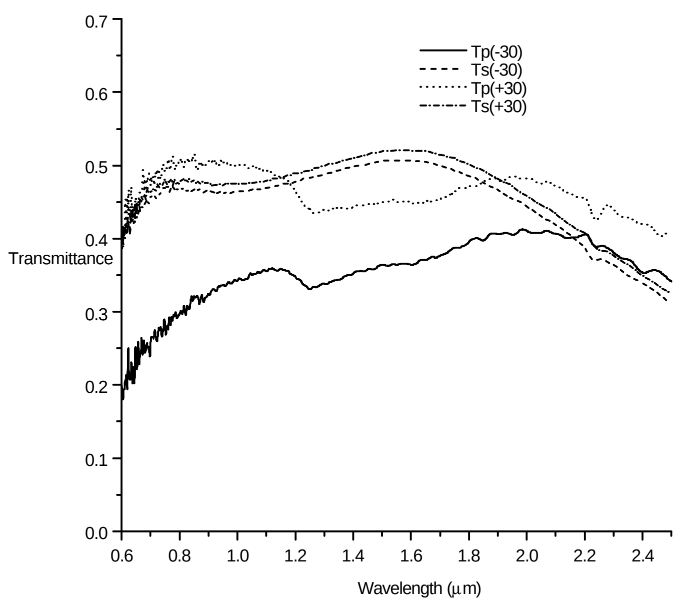

Figure 4 Tp and Ts as a function of wavelength at plus and minus 30 °, either side of the normal.

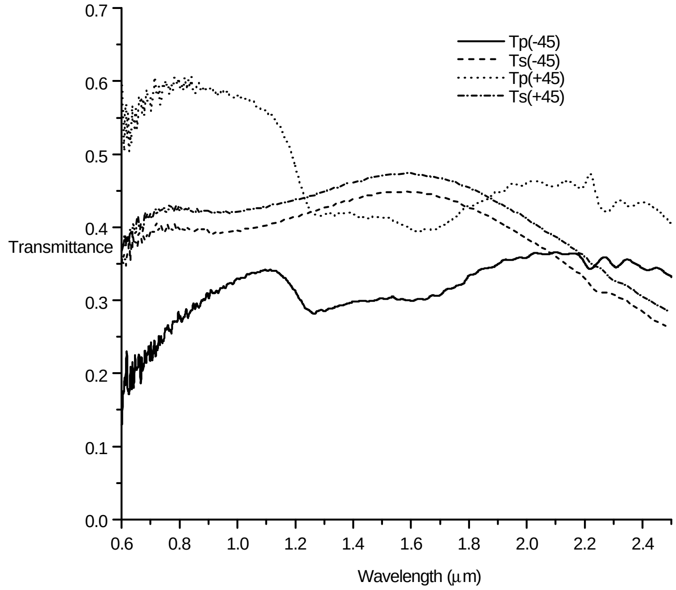

Figure 5 Tp and Ts as a function of wavelength at plus and minus 45 °, either side of the normal.

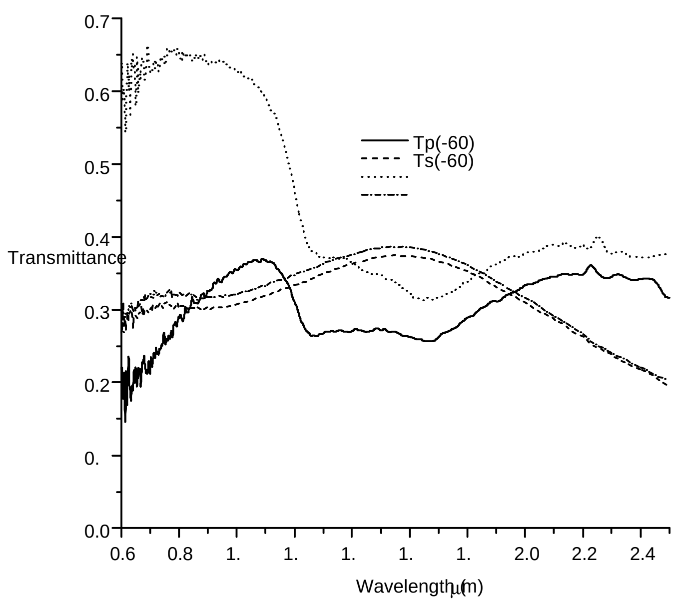

Figure 6 Tp and Ts as a function of wavelength at plus and minus 60 °, either side of the normal.

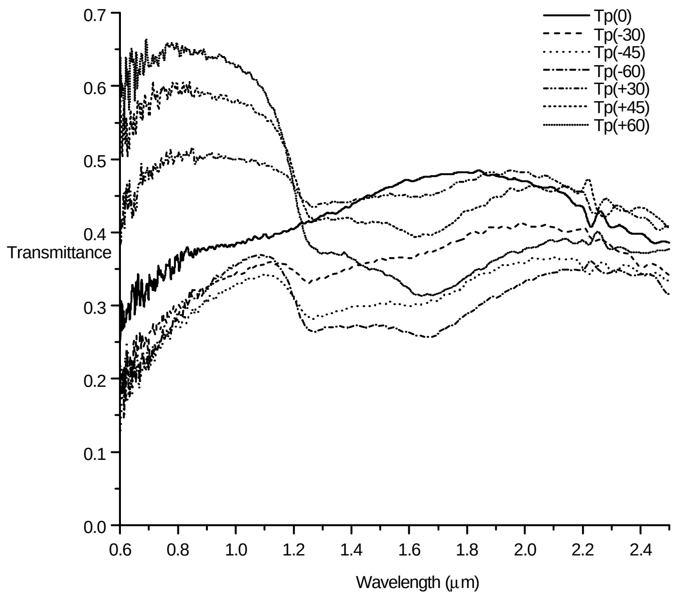

Figure 7 Tp as a function of wavelength at angles of incidence either side of the normal, (-60°, -45°, -30°, 0°, +30°, +45°, +60°).

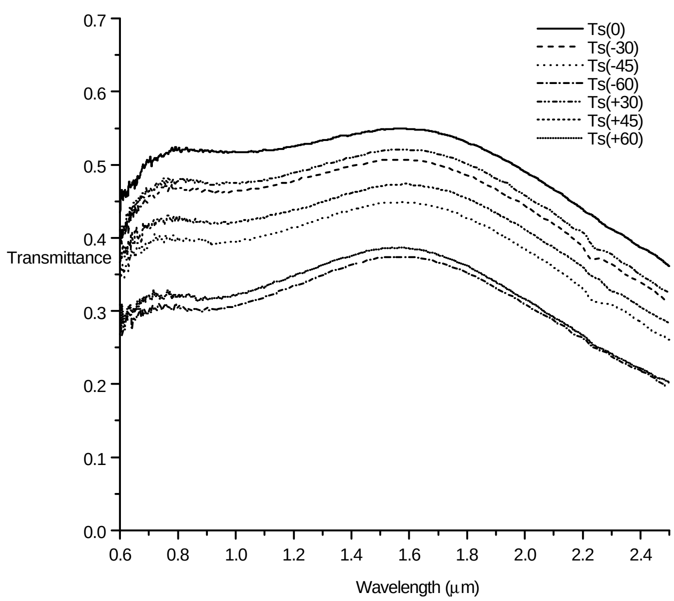

Figure 8 Ts as a function of wavelength at angles of incidence either side of the normal, (-60°, -45°, -30°, 0°, +30°, +45°, +60°).

4. References

1. Defence Standard 00-23/Issue 1, NATO Infra Red Reflective (IRR) Green Colour for Painting Military Equipment, Ministry of Defence, 17 October 1980.

2. Hutchins M G and Ageorges P, '*Intercomparison of measurements of spectral transmittance and reflectance at different angles of incidence*.' Bureau de Reference Project 3413/1/0/177/1/91/-BCR-UK(30), Final Report, July 1992.